RD 2012-5 Physics Simulations: Progress Report & Proposal

Thomas Ullrich, BNL

EIC Generic R&D Advisory Committee Meeting
January 13-14, 2014

BROOKHAVEN NATIONAL LABORATORY

RD 2012-5

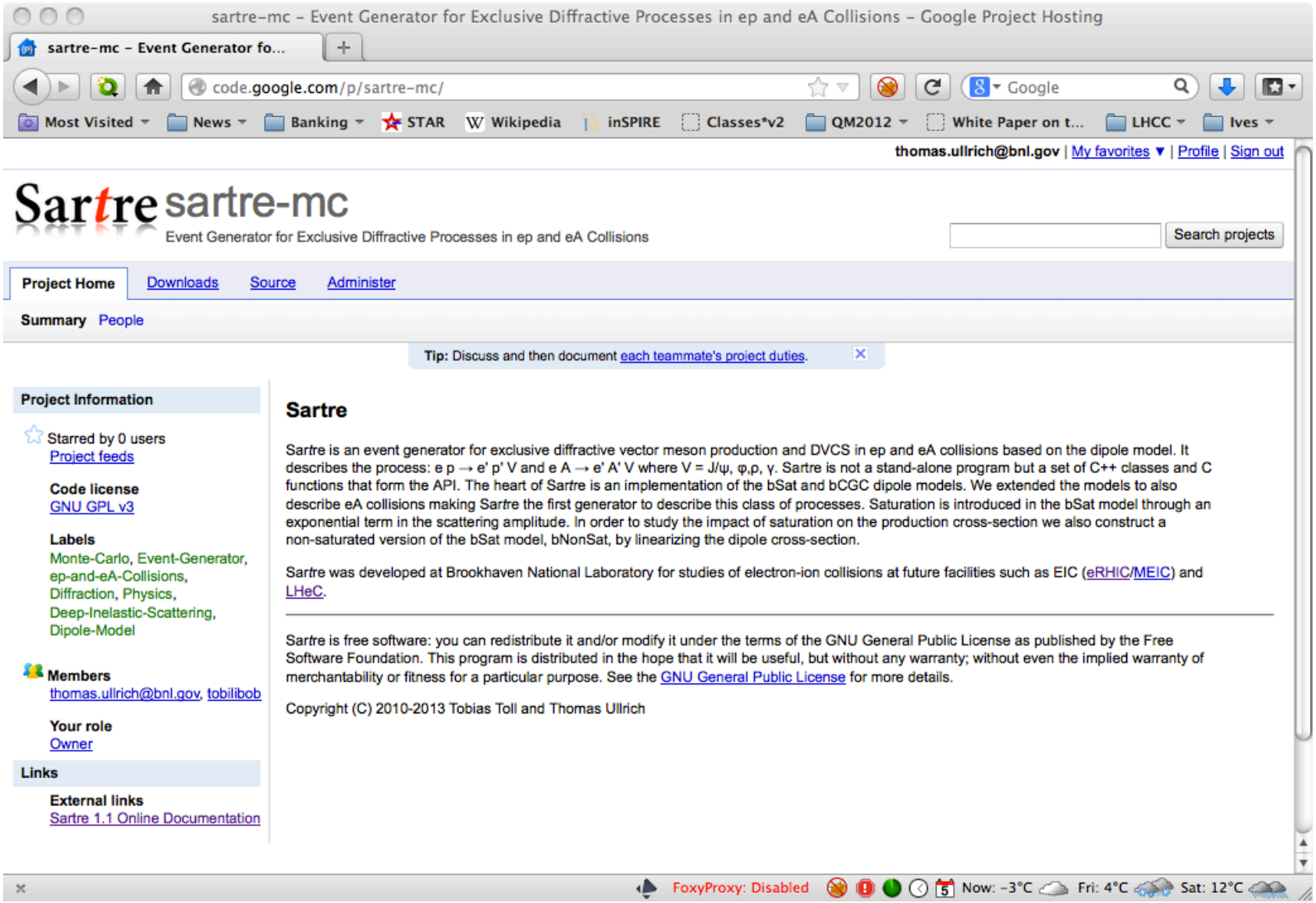
- Design and implement event generators for eA
  - include saturation and non-saturation modes
  - available for the EIC community
    - well documented
    - accessible to everyone
- May 2, 2012: official start of RD 2012-5
  - Manpower: Tobias Toll (paid out of R&D funds) & TU
- May 2, 2014: official end

Achievements (I)

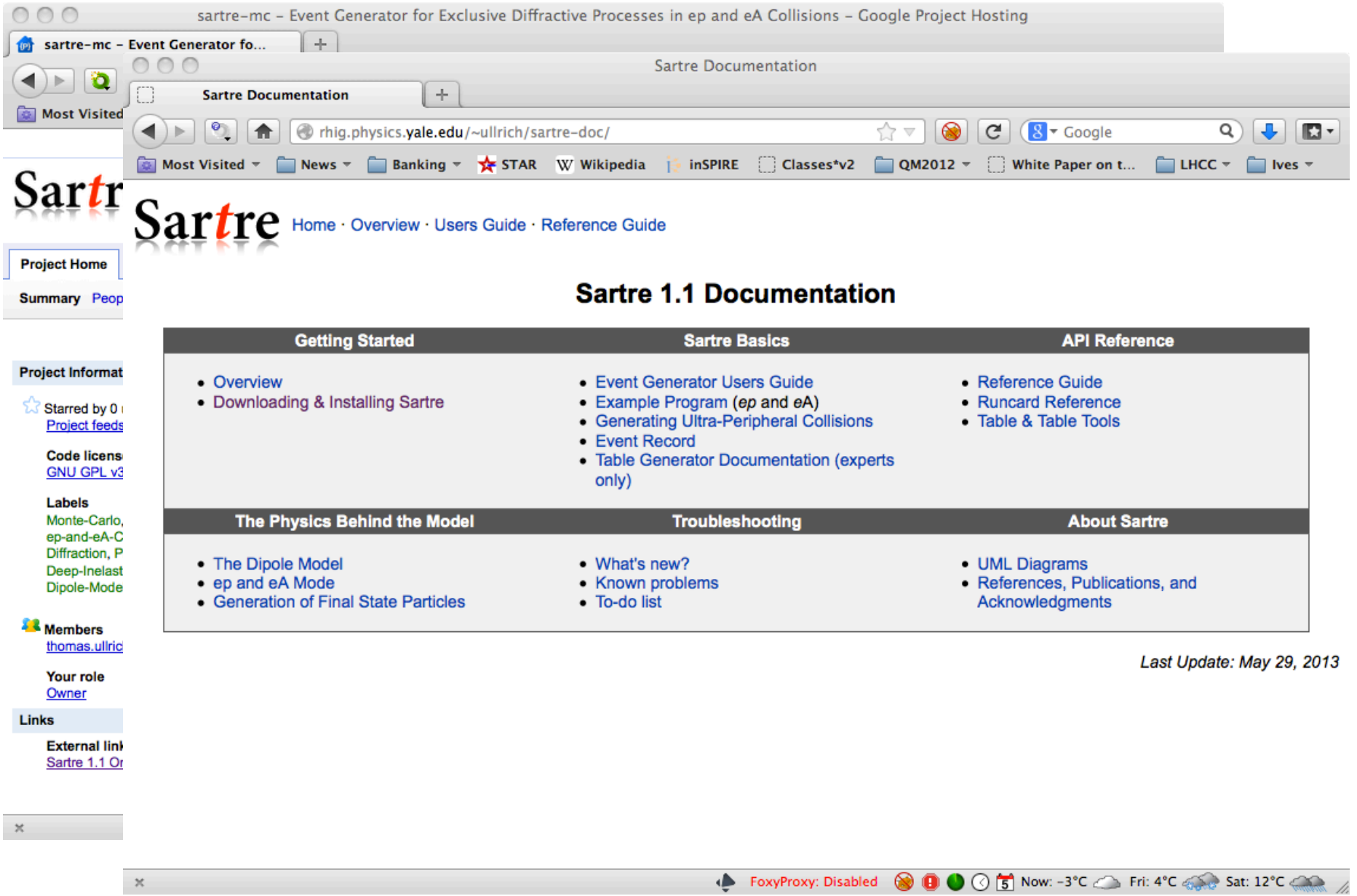
Sartre 1.1

- first event generator for diffractive events in ep **and** eA
- saturation and non-saturation mode
- limited to exclusive vector meson production
- based on impact parameter dependent dipol model(s)
- full nuclear geometry (spherical nuclei) incl. nuclear breakup
- tuned to describe HERA results
- well documented: reference and user guide
- Publications:
  - physics: Phys. Rev. C87 (2013) 024913
  - technical: submitted to Comp. Phys. Commun. (arXiv: 1307.8059)
- user community slowly growing (US, China, Europe)
- dedicated web site: https://code.google.com/p/sartre-mc

Achievements (II)

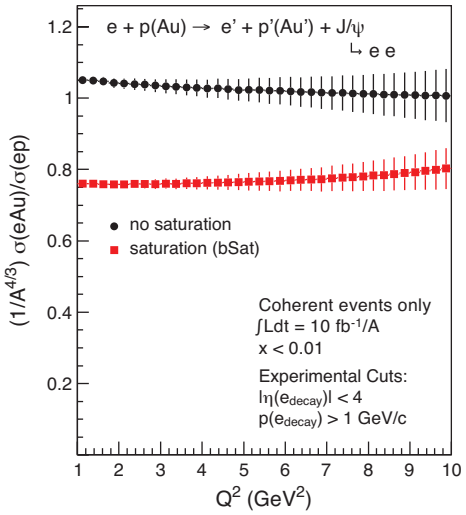


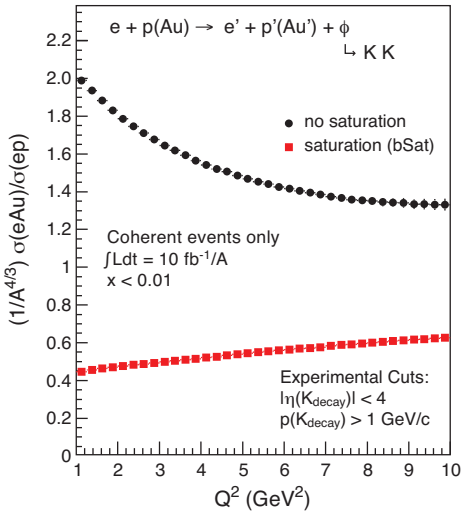
Achievements (II)



Achievements (III)

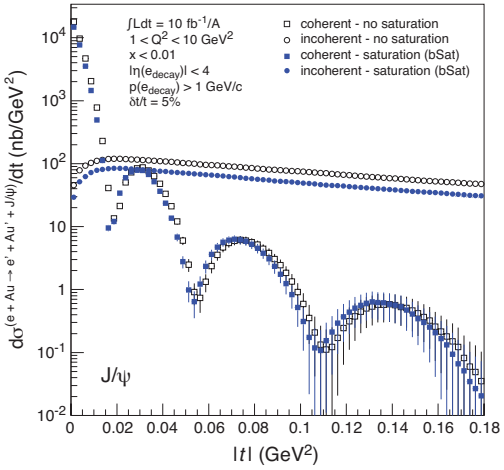
Sartre was extensively used in the realization of the EIC White Paper (arXiv:1212.1701):

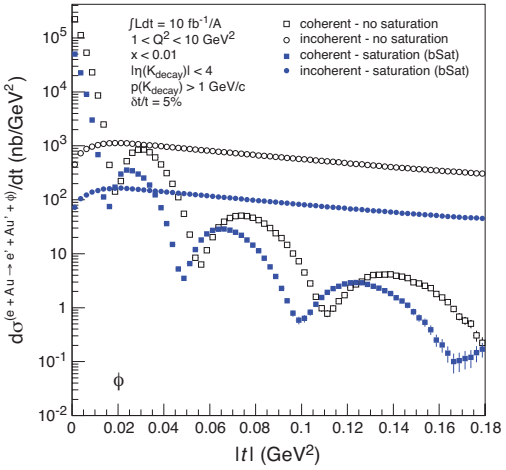




$$
\begin{aligned}
e + p &\rightarrow e' + p' + V \\
e + \mathrm{Au} &\rightarrow e' + \mathrm{Au}' + V \\
\text{where } V &= J/\psi, \phi, \rho, \gamma
\end{aligned}
$$

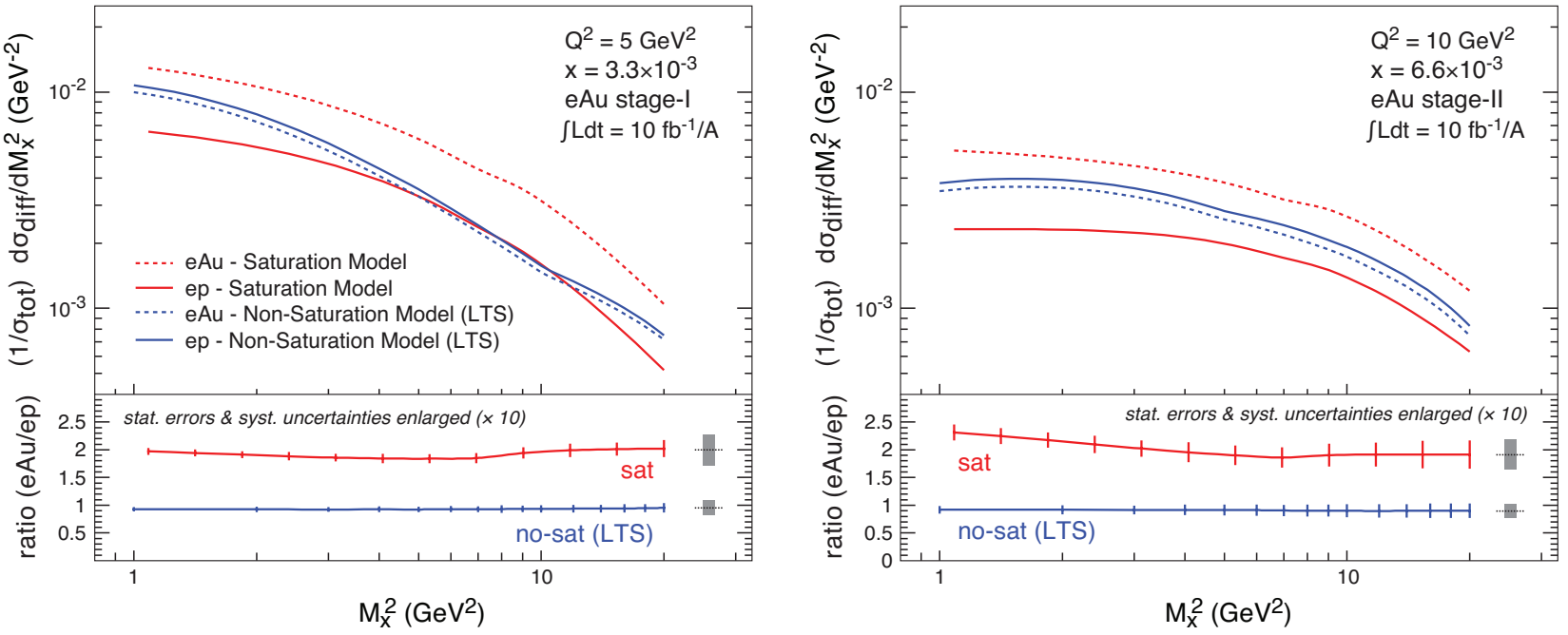
Exclusive VM production is a key measurement in the EIC eA program





Limitations of Sartre 1

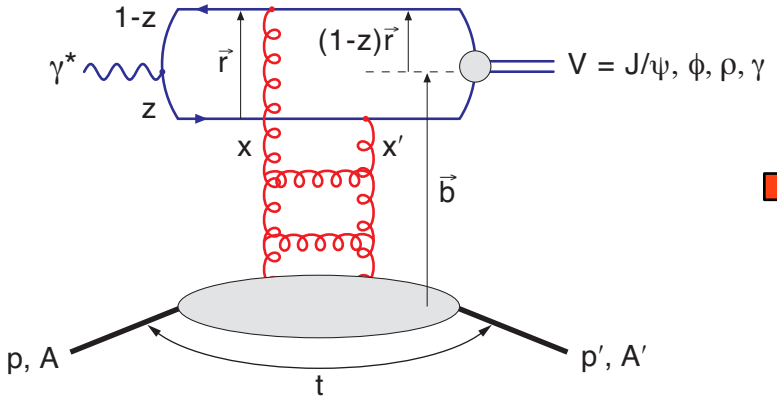
- Diffraction in eA is of great importance for an EIC
- Current limitation to exclusive production became an issue
- In White Paper inclusive diffractive signatures where provided by colleagues from theory
  - no possibility to filter through detector simulations
  - long turn-around times

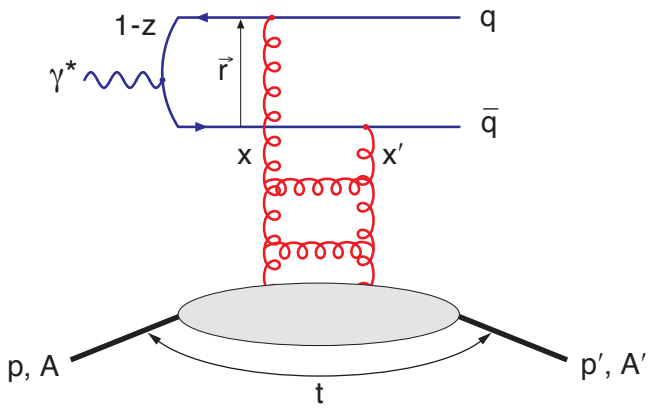


Overcoming Limitations

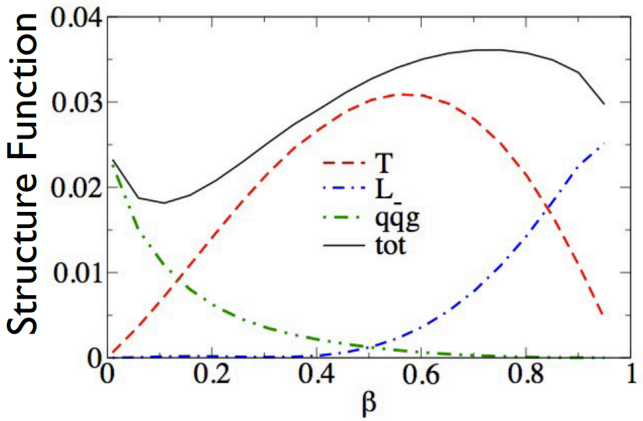
Extending Sartre to inclusive diffraction:

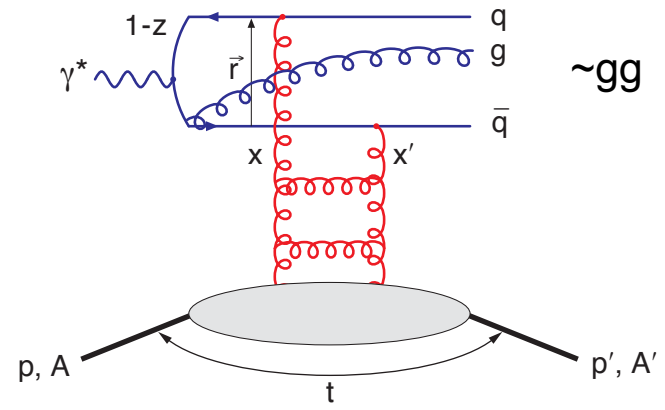
$$e + p \rightarrow e' + p' + X$$
$$e + \mathrm{Au} \rightarrow e' + \mathrm{Au}' + X$$





Need to include 2 processes: $\bar{q}q$ and $\bar{q}qg$



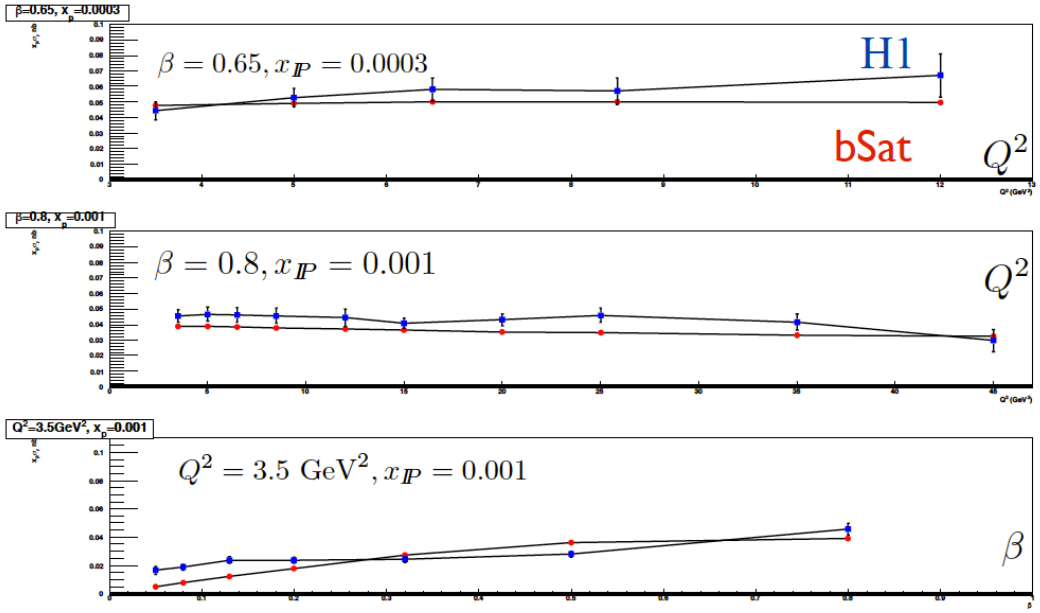


~gg

Achievements (IV)

Fall/Winter 2013: **Start to implement inclusive diffraction**

- Tobias performed all calculation (physics foundation) including the extensions to eA
- Currently implemented in Sartre in “calculation” mode
  - cross-section are calculated
  - no event generation yet

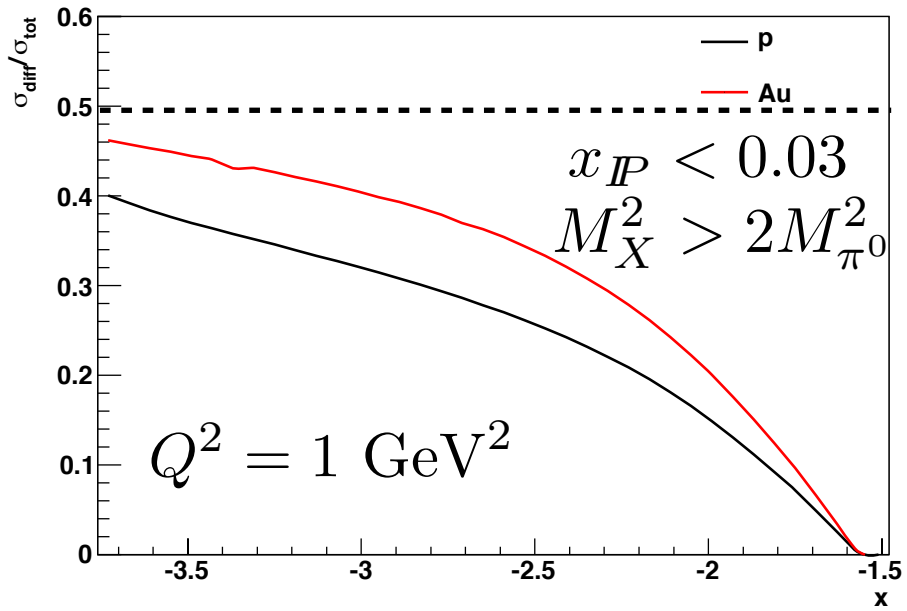


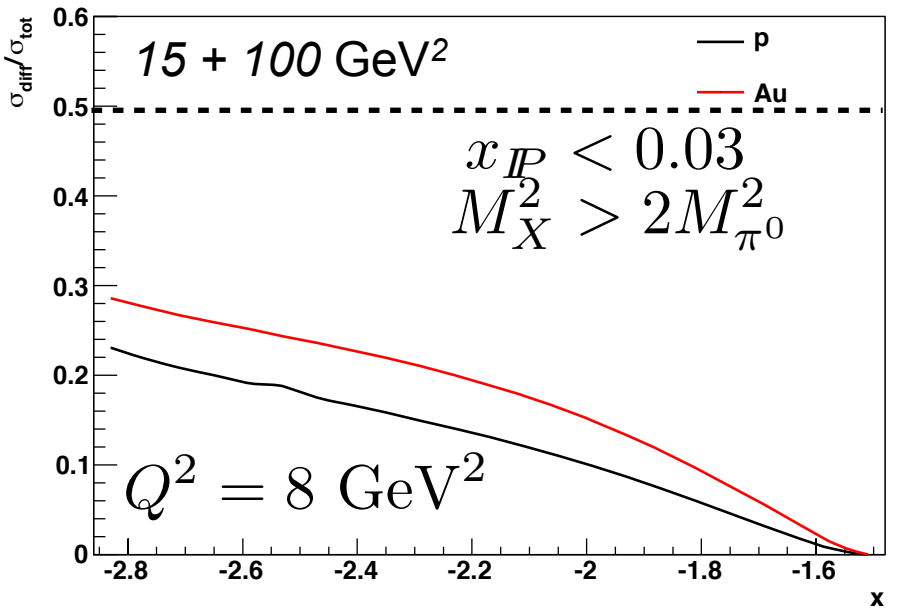
Excellent agreement with HERA/H1 data on ep mode

Achievements (V)

"Inclusive" Sartre

- eA matches well with theory calculation shown in WP
- Now important tool in investigating "critical" measurements





Sartre: Future Plans

- Redesigning Sartre 1.1 to include inclusive diffraction: Sartre 2.0
  - Changes in class structure needed
  - Generation of events via sampling from 4D cross-section tables
  - To generate particles: decay $\bar{q}q$ and $\bar{q}qg$ in PYTHIA8
    - simply linking with PYTHIA8 library will suffice
    - provides “standard” output used in HEP and NHEP
- Critical Issues
  - Implementation, testing, and documentation is substantial effort, needs time
  - Critical ingredient for LRP preparations
- In parallel:
  - Massive computing efforts on OSG to produce a variety of amplitude tables to extend Sartre 1.1’s reach (Liang Zhang)
    - cover now LHC energies, more nuclei
  - Work in progress to extend to deformed nuclei (e.g. U)

What was not achieved yet?

With Sartre 2 covering all our needs for diffractive events the remaining item is a generator for (deep) inelastic collisions in eA

- Currently:
  - Hybrid: PYTHIA/EPS09/DPMJet-III (L. Zheng)
  - contains nuclear geometry, E-loss effects and nuclear breakup
  - lacks saturation implementation (comparison of sat vs. non-sat scenarios is key for EIC)
- Planned: CASCADE
  - ep, pp generator for HERA and LHC
  - CCFM evolution for parton showers
    - DGLAP for large x, BFKL for small x
  - Author: Hannes Jung (DESY)

CASCADE

- **Can be extended to eA**
  - requires unintegrated PDFs: $G(x,Q^2,k_T)$
  - saturation: stop/damp evolution for $k_T < Q_S$
- **To-Do**
  - fit the dipole model to HERA F_2 data with HERA-fitter
  - construct the nuclear scattering amplitude from the resulting fit.
  - construct the nuclear uPDF
  - DID generator: CASCADE + DPMJet-III (nuclear geometry)
- **Reasons for delay**
  - waiting for H. Jung to integrate CASCADE into HERA-fitter.... (Hannes is hard to come by)
  - inclusive diffraction had higher priority

Status

	DIS		Diffractive	
	saturated	non-saturated	saturated	non-saturated
exclusive	✗	✓	✓	✓
	✗	✓		
inclusive	✗	✓	(✓)	(✓)
	✗	✓		

Know how to solve
Need uPDF fits

Work in progress

Proposal

R&D Project ends May 2, 2014

To Do:

- Sartre 2 (inclusive diffraction)
- Finalize CASCADE

Both not realistically feasible in remaining time

Tobias has likely prospect for junior professorship

- appointment likely not before end of July 2014
- opportune window to complete outstanding To-Do items

Request extension of the R&D program by 3 month

- finish remaining task (needed for LRP preparations)
- bridge Tobias's employment, allowing smooth transition

Take Away Message

- Exclusive Diffraction (Sartre 1.1) ✓
- Inclusive Diffraction (Sartre 2.0)
  - mathematical apparatus implemented and tested
  - generator part to be coded, tested, and documented
- Deep Inelastic Scattering
  - Hybrid solution for DIS exist and works for non-saturated scenario
  - CASCADE needs work
    - path to extend it to eA is well defined
    - would cover saturated and non-saturated scenarios
- Request extension by 3 month to complete remaining items